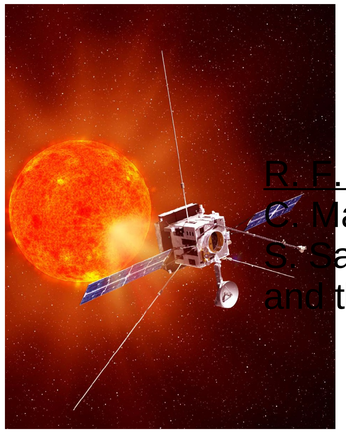

The Energetic Particle Detector (EPD) for Solar Orbiter: Sensor Status and Calibration

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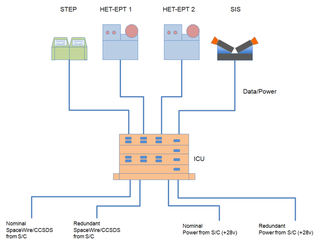
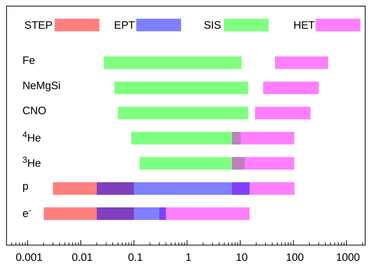
Abstract:
Solar Orbiter will solve the puzzle how the Sun creates and controls the heliosphere, the giant plasma bubble which forms as a result of the interaction of the solar wind with the local interstellar medium. Energetic particles are part of this puzzle and help understand the various driving forces and energy release processes in the solar corona. The Energetic Particle Detector (EPD) will determine how the Sun energizes particles to very high energies and sometimesfills the heliosphere with particle radiation. It consists of a suite of sensors which will measure protons (electrons) from 3 (2) keV up to 100 (20) MeV and ions from few tens of keV/nuc to 200 MeV/nuc. We will discuss the scientific aims of EPD as well as the current status and calibration of the EPD sensor (STEP, EPT, SIS, HET).

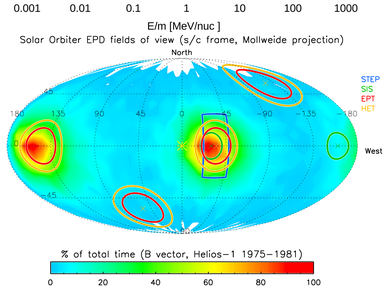
EPD

Energetic Particle Detector



EPD consists of the four sensors STEP, EPT-HET-1, EPT-HET-2, and SIS. They have been chosen to optimize science return (energy, composition, and pitch-angle coverage) within an array of different constraints. The sensors hook up to the EPD ICU which interfaces to the spacecraft.





Acknowledgements:

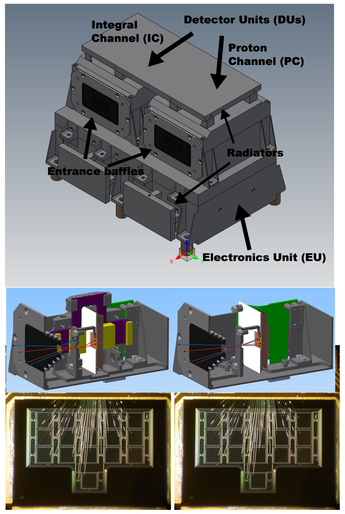
EPD is funded by the Spanish Ministerio de Economia y Competitividad (MINECO) and the German Space Agency (DLR) under contract 50 OT 1202; SIS is an ESA-funded facility sensor.

STEP

SupraThermal Electron Proton sensor

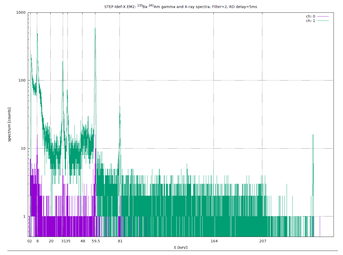
STEP has two sensor heads which measure electrons and ions (integral channel) and ions only (ion channel). Electrons are swept aside by a strong magnet system in the ion channel, thus allowing for a clean ion measurement. The magnet system has been designed to be 'self contained', i.e., results in a minimal far field.

STEP was moved from the boom to the spacecraft and underwent a complete redesign. Its status trails that of EPT-HET by a few months. QM parts are being manufactured.



Detector system resolution:

The STEP detectors have ultra-thin entrance windows which allow us to measure low-energy protons (~3keV) and electrons (~2keV). The multi-pixel detector is read out by the Idef-X-BD ASIC, the combined resolution of ~350 eV is shown in the figure to the right.



Ions and electrons:

STEP will be calibrated at the CAU calibration facility which features electrons from 10 eV – 100 keV collimated to a pencil beam (red circle) and an ion beam with energies from few keV/q up to 450 keV/q. A 5-axis positioning unit has been installed in the 1.2m diameter vacuum chamber. The facility is located in a ISO 7 clean room, the chamber door under an ISO 5 tent.

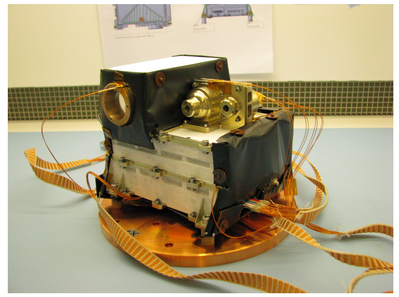
Ion beam entrance flange.

Electron-gun collimator.

EPT-HET

Electron Proton Telescope – High Energy Telescope

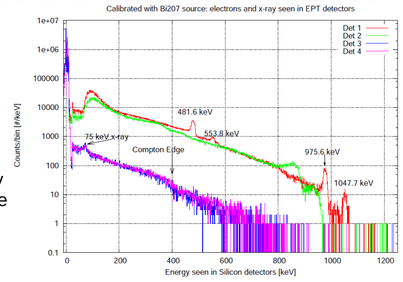
Two EPT-HET sensor heads are being developed to allow for limited pitch-angle coverage. EPT is based on STEREO-SEPT heritage, HET on MSL/RAD. EPT separates electrons from protons again with a self-contained permanent magnet system. HET extends EPD's energy range to 100 MeV protons, as shown in the energy-coverage figure in the very left panel.



The EPT-HET STM was delivered to Astrium UK (now Airbus DS) in September 2013. The EM has been tested and the PQM is being assembled.

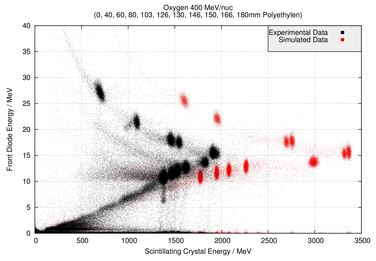
Electron discrimination/resolution:

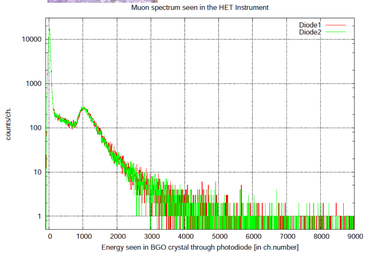
Electron resolution and separation can be seen in the figure to the right. The red line shows 207-Bi calib measurements in the electron channel, the green line shows the same for the proton channel. Low-energy electrons are not seen in the proton channel, the high energy electrons lie beyond the energy range of EPT.



HET calibration:

Muon spectrum seen in the HET Instrument





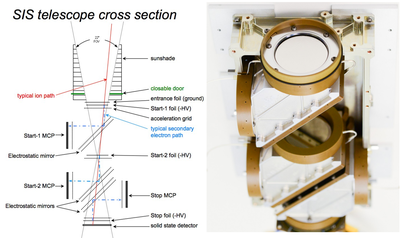
HET will be calibrated with heavy ions at HIMAC in Chiba, Japan. The left hand figure shows calibration data acquired with the HET demo model in black. Red dots show simulation data without quenching. This demonstrates the importance of this effect. The right-hand figure shows measurements of cosmic muons at sea level. These relativistic particles deposit the smallest expected amount of energy in HET.

SIS

Suprathermal Ion Spectrograph

SIS has two near-identical time-of-flight telescopes which end in a 650 micron thick solid-state detector. Both are supported by a common electronics box which also serves as the bracket to the spacecraft.

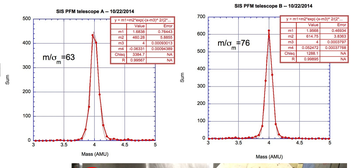
SIS EM during vibration testing.



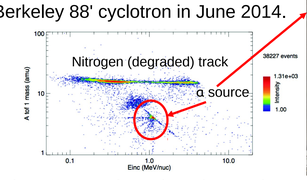
The time-of-flight arrangement can be seen in the schematic to the left and a SIS-FM telescope (which has been rotated to correspond to the schematic).
The time of flight and energy measurement result in exceptionally good resolution, as is exemplified in the plots below.

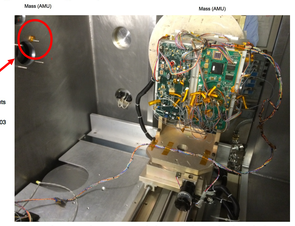
Alpha-particle resolution:

SIS FM alpha-particle resolution shows the expected behavior and allows separation of the He isotopes down to very small isotopic ratios of ~1%.



The SIS EM was calibrated at the Berkeley 88' cyclotron in June 2014.





The SIS PFM is undergoing environmental testing and is scheduled for its pre-ship review end January 2015. It will then be stored at APL.

EPD successfully underwent CDR end 2013/early 2014, FM delivery to the spacecraft is foreseen in April 2016. QM environmental testing is foreseen in March 2015, EPT-HET & STEP FM environmental tests in fall 2015 with subsequent suite-level integration and testing at UAH.

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